CONSTELLATION X-RAY MISSION AND SUPPORT

NASA Cooperative Agreement NCC5-368

Fourth Annual Report

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Principal Investigator

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1.0 Introduction

This Fourth Annual Report summarizes work performed by the Smithsonian Astrophysical Observatory (SAO) for NASA Goddard Space Flight Center (GSFC) under Cooperative Agreement NCC5-368[1]. The Agreement is entitled "Constellation X-ray Mission Study and Support."

SAO continues to perform work under the overall direction of Dr. Harvey Tananbaum, the SAO Principal Investigator for the program. Mr. Robert Rasche is the SAO Program Manager and is responsible for day-to-day program management at SAO and coordination with GSFC.

The report summarizes the main areas of SAO activity. Most of the work has been done jointly with personnel from GSFC and Marshall Space Flight Center (MSFC). We describe SAO participation in these efforts.

As is appropriate to a Cooperative Agreement, SAO continued to work with GSFC in an integrated team mode. SAO was involved in the overall mission management, technology development, scientific direction, and mission definition. Figure 1 summarizes the project organization during the reporting period. While formal overall management responsibility resides with GSFC, scientific lead and subordinate responsibilities continue to be shared by GSFC and SAO.

The work performed by SAO is consistent with the SAO proposal "Constellation X-ray Mission Study and Optics Development" dated September 1997, which was the basis for establishing the Cooperative Agreement under which SAO is currently funded. Over time, the scope of the effort has expanded somewhat to accommodate the needs of the project. Work, except for meeting support and high priority program tasks, has been at a level of effort. Priorities and work progress have been closely coordinated with the Constellation-X Project Formulation Manager at GSFC. Funding limitations constrained the work accomplished during this period.

Nonetheless, a significant amount of work was accomplished. Under the Agreement, SAO performed work in seven major areas of activity. These areas related to:

- Constellation X-ray Mission Facility Definition Team and Study Management
- Science Support
- Spectroscopy X-ray Telescope (SXT)
- Systems Engineering
- Travel in Support of the Work Effort
- In-house Management and Coordination

The following sections summarize work performed by SAO during the reporting period.

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[1] In subsequent text, NCC5-368 is simply referred to as the "Agreement". A Cooperative Agreement is the appropriate vehicle for the close, flexible, and wide ranging interaction between SAO and NASA needed to ensure the success of the Constellation-X project formulation activity.

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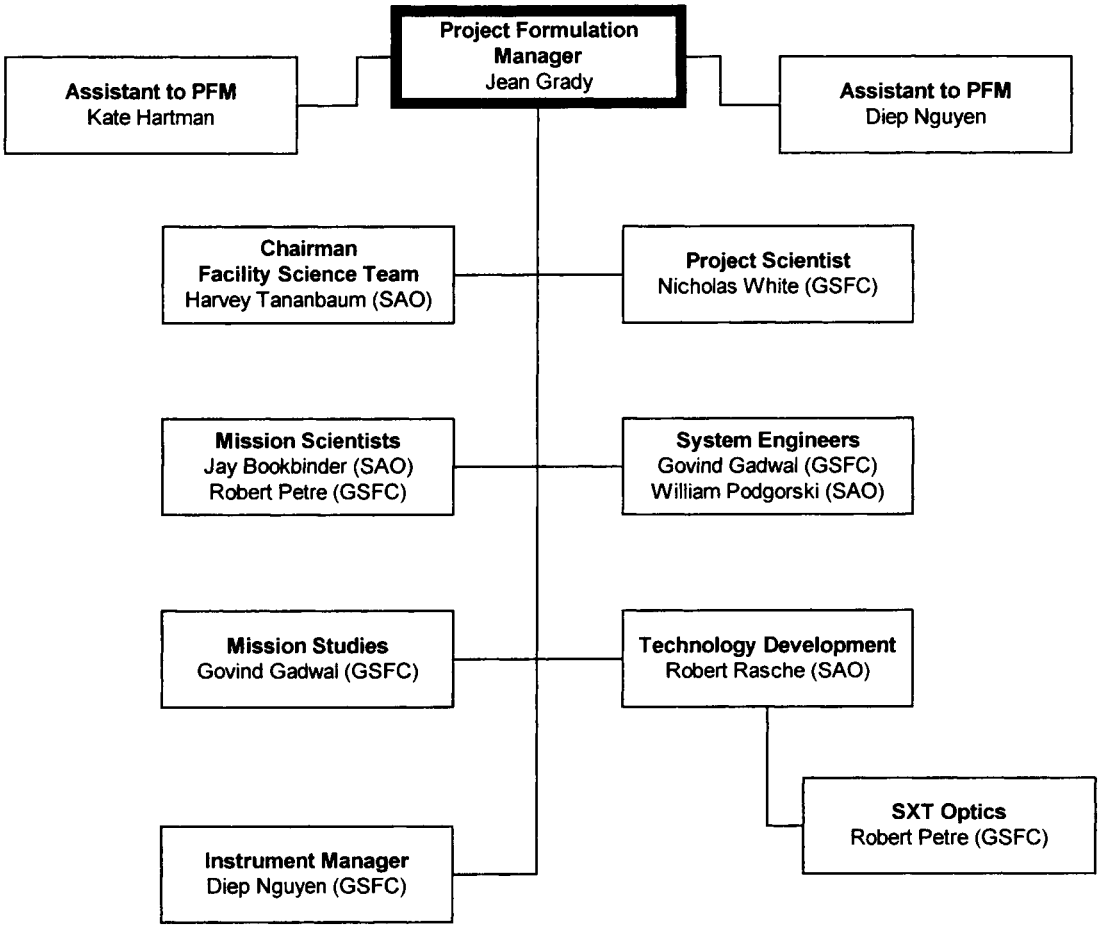

Figure 1

Constellation-X

Project Organization Chart

2.0 Constellation X-ray Mission Definition Team and Study Management

2.1 General Study Management and Coordination

SAO continued to be heavily involved in Constellation-X mission definition and the overall management of the study. Management decisions generally involved the Project Scientist, Dr. Nicholas White (GSFC), the Facility Science Team Chairman, Dr. Harvey Tananbaum (SAO)[2], the Project Formulation Manager, Ms. Jean Grady (GSFC), and the SAO Program Manager, Mr. Robert Rasche. Frequently the two Mission scientists, Dr. Jay Bookbinder (SAO) and Dr. Robert Petre (GSFC) were also involved. Dr. Kimberly Weaver of GSFC assumed the duties of Deputy Project Scientist.

SAO was a major participant in the technical overview, planning, and review of both future work and work in progress with particular emphasis on the SXT Mirror Assembly and its related Optical Assembly Pathfinder, Engineering Unit, and Prototype assemblies.

SAO continued to be involved in the management of mission definition activities, particularly with regard to thermal control, error budget development, and developing both science and mission requirements and resultant flow-down requirements. SAO personnel brought extensive and relevant experience from CHANDRA, HEAO, TRACE, HST, and other programs to the Constellation-X mission definition work.

Drs. White and Tananbaum had primary responsibility for scientific management with support from Drs. Bookbinder (SAO), Weaver (GSFC), and Petre (GSFC) and, occasionally, others. This included coordination with members of the Facility Science Team, interactions with NASA Headquarters and the science community at large, as well as participation in the Constellation-X Study Team meetings that were held approximately every two weeks at GSFC. Other special meetings were also supported.

The SAO management team participated aggressively in establishing plans, budgets, presentations, and priorities. This has been and continues to be an on-going and more or less continuous activity.

2.2 Technology Development Management and Coordination

Under the Agreement, SAO has an important role in managing and coordinating technology development for Constellation-X. That role continued through the reporting period. The organization chart on page 2 shows Mr. Rasche responsible for coordinating technology development. He has been supported by other SAO staff and, of course, works closely with both GSFC and MSFC staff.

SAO's main technology management involvement has been related to the SXT X-ray mirror and the reflective gratings. However, SAO has also kept involved with instrument technology developments and related planning and budget negotiation. Diep Nguyen and Kate Hartman at GSFC are heavily involved with the instruments and handle the day-to-day interfaces. Since the IPT funding comes through GSFC contracts and grants, the SAO role has been primarily to provide expertise, coordination, and general overview to the instrument development work. SAO supports most project teleconferences related to instrument technology and essentially all teleconferences and/or meetings related to SXT mirror technology.

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[2] Because Constellation-X is a consolidation of their individually proposed and accepted programs into a single program, Drs. White and Tananbaum function as equal Co-Principal Investigators although they have well-defined and separate formal responsibilities.

During the reporting period, Dr. Webster Cash (U of Colorado) raised the notion of using off plane gratings rather than the base lined in plane gratings. Dr. Bookbinder (SAO) began both in depth familiarization with this technique and coordination and planning for a possible demonstration of the technology. Bookbinder worked closely with Hartman (GSFC) on this activity and continues to do so.

2.3 Reports and Presentations

SAO personnel developed and made presentations at many meetings. These meetings included the biweekly team meetings at GSFC, and related splinter meetings, as well as technical interchange meetings (TIMs). The TIMs have generally been related to work on the SXT OAP planning and implementation. SAO (Podgorski) presents at the monthly SXT Mirror Status Meetings.

2.4 Mission Studies

SAO personnel continued to make direct technical contributions to the ongoing mission studies at GSFC and to discussions and trades related to mission operations and instrument accommodation. This helps ensure that relevant CHANDRA (AXAF) experience (which is ongoing) in these areas is transferred to the Constellation-X program in an effective and continuous way. These contributions have tended to be related to systems engineering issues -- an SAO strength (see Section 5).

2.5 Coordination with Industry

SAO were involved in a number of interactions between the Constellation-X project and industry. These interactions have been both formal and informal. The objective is two-fold:

- Maintain a continued awareness of relevant technologies and interests.
- Encourage interest in Constellation-X project on the part of industry.

3.0 Science Support

3.1 Chair of the Facility Science Team (FST)

Under the Agreement, SAO provided and continues to provide the Chair of the Constellation-X Facility Science Team, the group of scientists who help guide the program with regard to scientific objectives and needed capabilities. Dr. Tananbaum serves as Chair and is assisted by the Mission Scientist, Dr. Bookbinder and other members of the FST from several institutions and, of course, the Project Scientist, Dr. White and his science colleagues at GSFC.

During the period of performance, Dr. Tananbaum was a point of contact for both general FST members as well as for the leaders of the instrument technology teams. This activity was closely coordinated with Dr. White at GSFC who carried out a similar function. In general, Dr. White was more involved with the Government members of the FST and Dr. Tananbaum worked with FST members from non-Government organizations.

3.2 Mission Scientist

As required by the Agreement, SAO provided the expert services of Dr. Jay Bookbinder who filled the position of the Mission Scientist from SAO. His GSFC counterpart is Dr. Robert Petre.

Dr. Bookbinder participated in team meetings at GSFC and SAO and was an active and direct technical contributor to the SAO team. He also carried out special assignments for the FST Chair, Dr. Tananbaum. Dr. Bookbinder brought substantial and relevant expertise and experience from TRACE, the ongoing Solar-B, and other NASA programs. Working with others, he continued to further define and document the Constellation-X Top Level Requirements. A significant amount of both analysis and coordination with others was required to carry out this activity.

3.3 Representation at Various Scientific Meetings

Drs. Tananbaum and Bookbinder attended and participated in scientific and advisory committee meetings during the period. Their participation at these events helped to promote the Constellation-X program by providing information about the program, answering questions, and soliciting inputs to help ensure a balanced, effective, and significant science program.

4.0 Spectroscopy X-ray Telescope (SXT)

During the reporting period, more SAO effort was applied to the Spectroscopy X-ray Telescope and, in particular, to its X-ray mirror[3] than to any other task. SAO performed SXT related work in six main areas:

1. SXT Management and Coordination
2. SXT Mirror Module Design
3. SXT Mirror Assembly and Alignment Studies
4. SXT Error Budget Development
5. Segment Mirror Mandrel Procurement
6. Flight Mirror Development Planning

4.1 SXT Management and Coordination

Working with the concurrence of the Project Formulation Manager at GSFC (Jean Grady), SAO provided extensive oversight and direction to the Constellation-X SXT mirror definition and development. This activity included but was not limited to:

- Participation in numerous status review and planning teleconferences
- Informal tracking of SXT work progress at MSFC, GSFC, and SAO
- Evaluation and informal reporting of progress to GSFC Constellation-X project office.
- Development and evaluation of work plans and budgets
- Formulation and presentation of recommendations for future plans and priorities
- General overview of SXT work

4.2 SXT Mirror Module Design

SAO continued in-house concept and analysis studies related to SXT segmented mirror concepts, and, in particular, the OAP and the engineering and prototype units that will follow it. William Davis (SAO) joined the effort and now provides essentially all of the precision structural analysis support to the ongoing work. In this role, Davis works closely with his GSFC counterparts and participates in telephone conferences and on site meetings at GSFC.

As work on the OAP has begun, SAO has tracked and evaluated the work as it progresses. This effort provides independent assessments and recommendations to the Project Formulation Manager.

4.3 SXT Mirror Assembly and Alignment Studies

SAO, together with its subcontractor Bauer Associates, has become an integral part of the OAP mirror adjustment and evaluation work. Dr. Podgorski and Mr. Glenn work in a hands on way

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[3] Technically the term Spectroscopy X-ray Telescope refers to the complete X-ray telescope. In practice, the term SXT and SXT Mirror have, unfortunately, come to be used interchangeably. The greater portion of SAO activity related to the SXT was directed at the X-ray mirrors per se.

with GSFC and MSFC colleagues. This work has and continues to involve structural analysis support from Davis (SAO). SAO has built and is about to deliver a temperature controlled chamber for OAP test at MSFC.

4.4 SXT Error Budget Development

Work on the SXT error budget continued during the reporting period and substantial progress was made. Dr. Podgorski (SAO) working with his GSFC counterparts has established an excellent working relationship between SAO and GSFC in the area of performance analysis and prediction. SAO also developed and is maintaining and enhancing an error budget for the OAP assemblies and related test set-ups.

4.5 Segmented Mirror Mandrel Procurement

SAO has participated in the overview of mandrel development work at Zeiss being carried out under a MSFC contract. SAO participates in monthly status meetings and reviews contract documentation. The first of three mandrels is about to be delivered to MSFC. This is an important milestone in that the mandrel satisfies our specification for the mandrel having the largest radius of curvature and hence the largest arc length. SAO continues to monitor procurements of mandrels for the technology program. Rasche (SAO) has been most involved in this effort (see below).

4.6 SXT Flight Mirror Program Planning

Useful SXT mirror technology will almost certainly be constrained by at least three factors related to flight mirror development rather than mirror technology per se. These factors are:

- Availability of required infrastructure and expertise
- Ability to obtain required infrastructure where none exists
- Corporate willingness to accept a contract for large flight or even prototype mandrels, particularly when compared with other business opportunities.

Working with Dr. Zhang and others at GSFC, Rasche (SAO) began to develop a reference approach to flight mandrel procurement and continued to maintain and expand an excellent working relationship with Zeiss and, to a lesser degree with Schott.

5.0 Systems Engineering

SAO continued to provide systems engineering support to the Constellation-X project. Work was mainly concentrated in five areas:

- Thermal control
- Requirements and requirements flow down development
- Opto-structural analysis of segmented SXT concepts
- System error budgets

5.1 Thermal Control

SAO and GSFC continued to work together in the areas of both instrument and overall system thermal control. In particular, Boyd and Freeman at SAO and Wes Ousley at GSFC have continued to review the system as it develops and coordinate closely with each other. Effort by SAO in this area was limited primarily by available funding. SAO continued work related to SXT Mirror Assembly temperature control and to refining concepts developed earlier.

5.2 Requirements and Requirements Flow Down

The Constellation-X Top Level Requirements have been defined although a few of them may be modified. Recent work continues to focus on flow down requirements on the various Constellation-X subsystems. This work is being done primarily by Drs. Bookbinder and Podgorski with the participation and review of others as appropriate. This work included analysis and research related to establishing numerical values for the various requirements.

5.3 Opto-Structural Analysis of Segmented SXT Concepts

As indicated in Section 4.2 SAO provided optical and structural analysis support to the emerging SXT Engineering Unit effort. SAO also was heavily involved and continues to be involved in the systems (and structural) engineering related to the Constellation-X gratings.

5.4 System Error Budgets

Some, but not much work was done during the reporting period to extend system error budgets. Work constrained primarily by funding limitations. This important activity will receive much more attention in the coming year, particularly in regard to those components associated SXT mirror assembly design concepts.

6.0 Travel

The Agreement provided funding for frequent program travel. Most, but certainly not all, of the travel was between SAO and either GSFC or MSFC.

With few exceptions, a Constellation-X Study Team meeting was held at GSFC every other week between 1:00 p.m. and 3:00 p.m. with splinter meetings on either side of this fixed time. This arrangement allowed SAO personnel to travel from Boston to GSFC and return on the same day with substantial savings in lodging and per diem costs. These meetings were usually attended by at least one SAO person and occasionally by three or four if required by either the meeting agenda or related splinter meetings. Whenever possible, splinter meetings were set up on the same day as the team meetings. These meetings were usually technical interchange meetings that took the form of informal working meetings. However, some of the splinter meetings were management review and planning meetings.

When appropriate, Rasche visited GSFC for two days, one day for the Study Team Meeting and related splinters and the second day (either before or after) for informal management discussions with Jean Grady and others. This has worked quite well and will be continued over the coming year. Other SAO personnel generally have made a one-day trip to support the Study Team Meeting and sometimes related splinter meetings.

SAO staff working on SXT mirror technology traveled to GSFC and to MSFC. These trips related primarily to OAP planning with emphasis on alignment and test.

7.0 In-House Management and Coordination

In addition to the direct participation in the Constellation-X project summarized above, SAO carried out housekeeping, coordination, and planning activities at SAO. This work related to the orderly operation of the SAO Constellation-X team.

These activities included:

- Cost planning, tracking, analysis, and control
- Personnel evaluation inputs
- Purchasing and logistics
- Coordination and information meetings
- Travel arrangements

SAO did not produce any stand-alone formal documents as such during the period of performance. Analyses, error budgets, area vs. energy plots, and requirements were developed and documented as informal documents, particularly by Bookbinder, Cohen and Podgorski. These were distributed in a timely way as attachments to e-mail messages. The Constellation-X Top Level Requirements document and its companion Flow Down Requirements document are still in process and will, in any event, be released as project documents.